

Direct Photon Production in Au+Au Collisions at RHIC-PHENIX Experiment

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Abstract

Direct photons have been measured with the PHENIX experiment in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The direct photon result obtained with PHENIX-EMCal up to 18 GeV/c is consistent with the NLO pQCD calculation scaled by the nuclear overlap function. The measurement using internal conversion of photons into e^+e^- shows the enhancement of the yield comparing with NLO pQCD calculation.

Key words: relativistic heavy ion collision, quark gluon plasma, direct photon
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1 Introduction

Since photons do not interact strongly, direct photons are a powerful probe to study the initial state of matter produced in relativistic heavy ion collisions. They are emitted from all the states such as the initial state, the Quark-Gluon Plasma (QGP), and the final hadron-gas state. In addition, it is predicted that the contribution of photons from jet-photon conversion in the dense medium can be as large as the photon yield from hard scatterings [1].

In the 2004 Run, PHENIX recorded a high-statistics Au+Au data set. The new data set allows us to measure direct photons beyond the transverse momentum (p_T) of 10 GeV/c and also more precisely than before at intermediate p_T where thermal photons and photons from jet-plasma interactions are important. The PHENIX experiment can measure photons with two types of highly segmented electromagnetic calorimeters (EMCal) [2]. One is a lead scintillator sampling calorimeter (PbSc), and another is a lead glass Cherenkov calorimeter (PbGl).

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2 Measurement of mid- p_T direct photon

Measurement of direct photons is challenging because there is a large amount of background from decay of neutral mesons such as π^0 and η . It is estimated that the γ/γ_{bg} would be $\sim 10\%$ at the p_T range of 2-4 GeV/c, where thermal photon is expected to be dominant [3]. In order to extract direct photon signal, conventional subtraction method has been used. π^0 and η mesons are reconstructed via their two-photon decay mode. The p_T spectra of direct photons are obtained by subtracting the spectra of decay photons estimated based on the measured π^0/η from the p_T spectra of inclusive photons.

In addition to the conventional subtraction method, the analysis was carried out using a new method where real direct photons are measured by their virtual counterparts [4]. The idea is that all sources of real photons also produce virtual photons that decay into e^+e^- pairs with small invariant masses. The invariant mass distribution of e^+e^- pairs from virtual photons can be given by Knoll-Wada formula [5] for each virtual photon sources, such as direct photon, π^0 Dalitz and η Dalitz. The ratio of direct photons was obtained using the ratio of photon yield in different e^+e^- invariant mass region. Compared to the conventional subtraction measurement, the new technique (internal conversion method) improves both the signal-to-background ratio and the energy resolution at intermediate p_T . An excess of the signal over background has been seen as the red points of left panel in Fig. 1, which is consistent with the result of conventional subtraction method within the error.

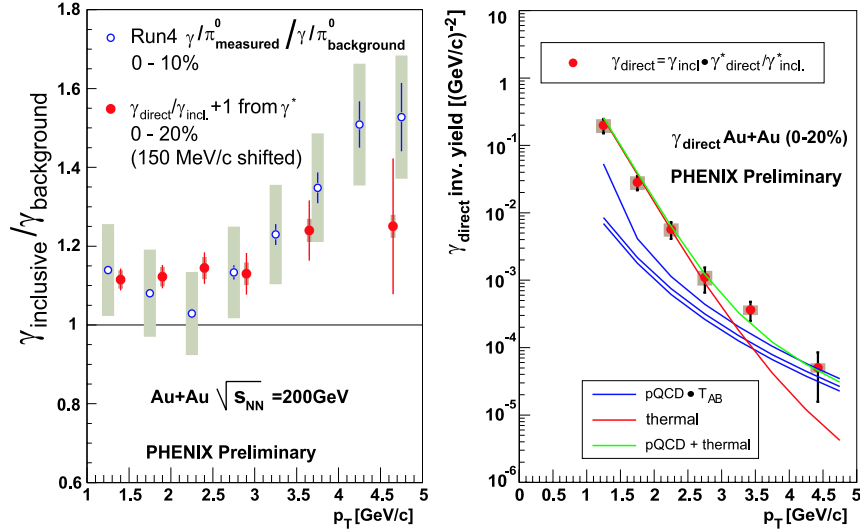


Fig. 1. Left: Direct photon excess ratio measured with subtraction method and with internal conversion into di-electron., Right: The direct photon spectrum from the measurement of internal conversion compared to NLO pQCD and hydrodynamics (QGP with $\langle T_0 \rangle = 360$ MeV) predictions.

The right panel of Fig. 1 shows the direct photon spectrum which is ob-

tained from the excess ratio measured with internal conversion method and inclusive photon spectrum measured with EMCal. The spectrum shows the enhancement comparing with the next-to-leading-order (NLO) pQCD calculation scaled by the Au+Au nuclear overlapping function (T_{AA}). $T_{AA}(b)$ is defined as $T_{AA}(b) = N_{\text{coll}}(b)/\sigma_{NN}$, where $N_{\text{coll}}(b)$ is the average number of binary nucleon-nucleon collisions at an impact parameter b with an inelastic cross section σ_{NN} . A hydrodynamical prediction which computes the thermal photon emission from a QGP with initial temperatures $\langle T_0 \rangle = 360$ MeV [6] supports the observed enhancement of the spectrum. However, the reference baseline in those calculations is the T_{AA} -scaled NLO pQCD photon spectrum. To confirm the existence of a thermal enhancement, it is necessary to directly measure the p+p direct photon spectrum in the $p_T = 1 - 4$ GeV/ c range.

3 Measurement of high- p_T direct photon

In contrast to the measurement of mid- p_T direct photon, the strong suppression of neutral hadrons by a jet-quenching effect in heavy ion collisions [7] allows to extract direct photons at the momentum region of $p_T > 5$ GeV/ c [8]. The left panel of Fig. 2 shows the direct photon excess ratio as a function of p_T in most central events (0-10%). The ratio is in good agreement with a NLO pQCD calculation [9] scaled by T_{AA} within the error and theoretical uncertainty. This suggests that the initial-hard-scattering probability is not reduced. The direct photon excess ratio measured by PbSc-EMCal slightly deviates from the NLO pQCD calculation above 14 GeV/ c . The deviation may support that the compensation of jet-quenching and additional photons by a nuclear effect, such as jet-photon conversion, is breaking up above 14 GeV/ c . Because the direct photon calculated with pQCD consists of the prompt photon produced from the hard scattering directly and the jet fragmentation photons coming from hard-scattered partons, the direct photon yield measured in Au+Au collisions is naively expected to be suppressed comparing with NLO pQCD calculation scaled by T_{AA} . The agreement with scaled NLO pQCD calculations might just be a coincidence caused by mutually counterbalancing effects like energy loss and Compton like scattering of jet partons [10]. In order to conclude that the deviation attributes to the such nuclear effect, it is important to measure high- p_T direct photon in p+p system and to observe the deviation with PbGl-EMCal as well.

The right panel of Fig. 2 shows the fully corrected direct photon invariant yield as a function of p_T for each centrality. The spectra are combined results of PbSc measurement and PbGl measurement. The yields are in good agreement with T_{AA} -scaled NLO pQCD calculation up to 14 GeV/ c .

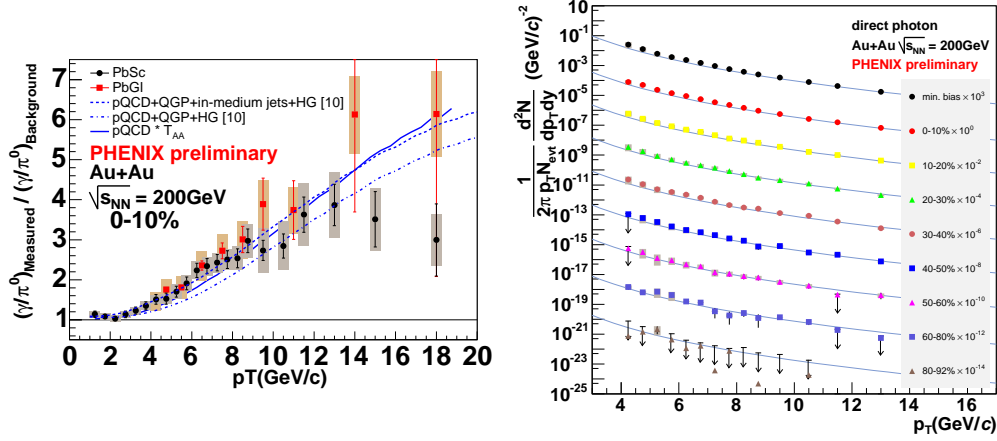


Fig. 2. Left: Direct photon excess ratio up to high- p_T measured with subtraction method. Three types of solid curves are theoretical curve: NLO pQCD scaled by T_{AA} , and a calculation which takes into account the jet-quenching of direct photons and photons from jet-plasma interaction. Right: The direct photon spectra for different centrality classes and minimum bias. The solid curves are NLO pQCD calculations scaled by T_{AA} .

4 Summary

The PHENIX experiment has measured direct photons in Au+Au collisions at $\sqrt{s_{NN}} = 200$ GeV. The large amount of data taken in RHIC Run4 has made it possible to extend p_T region up to 18 GeV/c. The result is consistent with the NLO pQCD calculation scaled by the nuclear overlap function. The measurement using internal conversion of photons into e^+e^- shows the enhancement of the yield comparing with NLO pQCD calculation.

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